



INTER-AGENCY LITHIUM-ION PROGRAM



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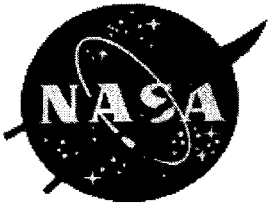
R. A. Marsh & R. James

U.S. Air Force Research Laboratory
Dayton, OH/Albuquerque NM

October 27-29, 1998

NASA BATTERY WORKSHOP

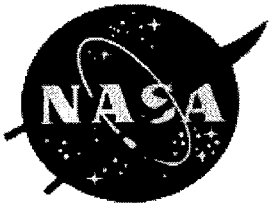
Huntsville, AL



OVERVIEW



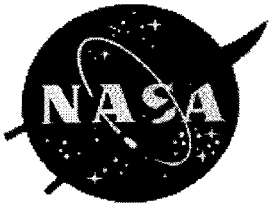
- Program Goals
- NASA Mission Requirements
- AF Mission Requirements
- Potential Near Term Missions
- Management Approach
- Technical Approach
- Program Road Map



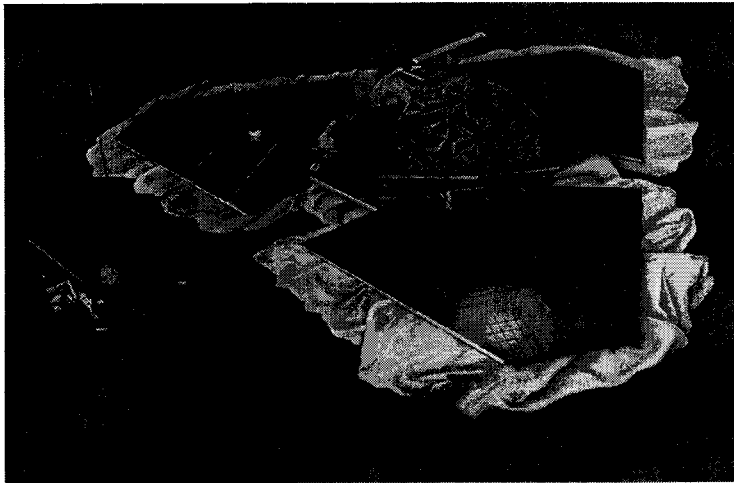
PROGRAM OBJECTIVES



- DEVELOP HIGH SPECIFIC ENERGY AND LONG LIFE LITHIUM ION CELLS AND SMART BATTERIES FOR AEROSPACE AND DOD APPLICATIONS.
- ESTABLISH U.S. PRODUCTION SOURCES
- DEMONSTRATE TECHNOLOGY READINESS FOR
 - ROVERS AND LANDERS BY JANUARY 1999
 - LIBRATION POINT MISSIONS BY 2000
 - GEO MISSIONS BY 2001
 - AIRCRAFT BY 2001
 - UAV BY 2003
 - LEO MISSIONS BY 2003

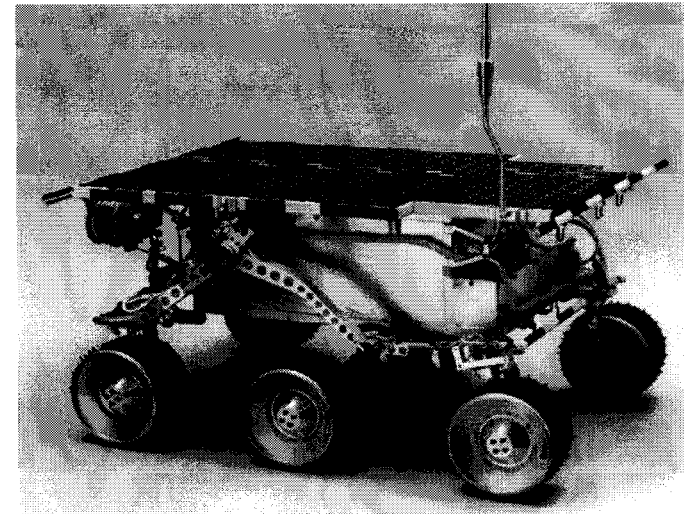


PLANETARY MISSION BATTERY REQUIREMENTS



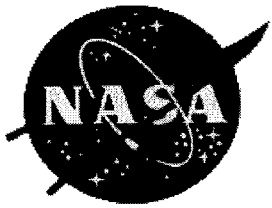
LANDERS

- CAPACITY: 20-40 AH
- VOLTAGE: 28V
- DISCHARGE RATE: C/10-C/5
- > 500 CYCLES (>50%DOD)
- -40 TO 50 C

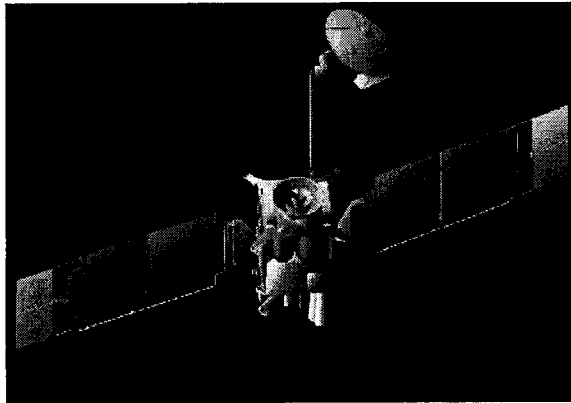
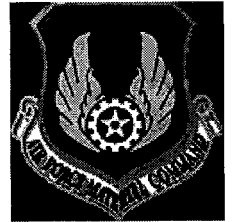


ROVERS

- CAPACITY: 5-20 AH
- VOLTAGE: 16 V
- DISCHARGE RATE: C/2-C/5
- > 500 CYCLES (>50%DOD)
- -40 TO 40 C



PLANETARY MISSION BATTERY REQUIREMENTS



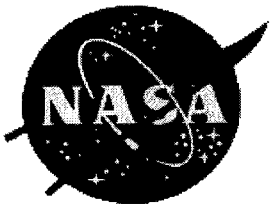
ORBITERS

- CAPACITY: 20-35 AH
- VOLTAGE: 28V
- DISCHARGE RATE: C/2-C
- > 30,000 CYCLES (>25%DOD)
- -5 TO 30 C
- >5 YEARS

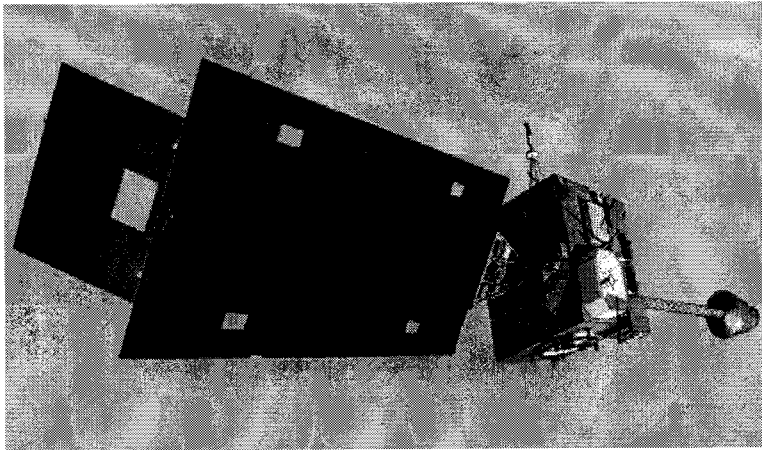


PENETRATORS

- CAPACITY: 0.5-2 AH
- DISCHARGE RATE: C/100-C/50
- > 300 CYCLES (>70%DOD)
- -80 TO 30 C

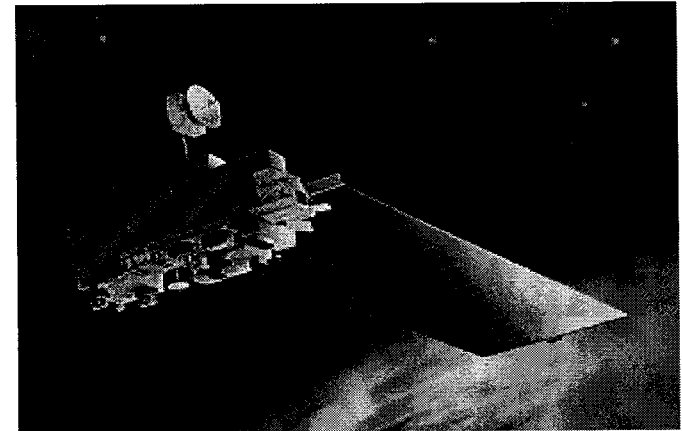


EARTH ORBITING MISSION BATTERY REQUIREMENTS



GEO SPACECRAFT

- CAPACITY: 10-35AH
- VOLTAGE: 28-100 V
- DISCHARGE RATE: C/2
- > 2000 CYCLES (>75%DOD)
- -5 TO 30 C
- 10-15 YEARS

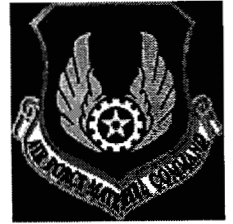


LEO SPACECRAFT

- CAPACITY: 10-35 AH
- VOLTAGE: 28 V
- DISCHARGE RATE: C/2-C
- > 30,000 CYCLES (>25% DOD)
- -5 TO 30 C
- >5 YEARS

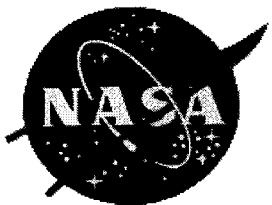


MISSION REQUIREMENTS



	LANDERS	ROVERS	GEO	LEO/ PLA. ORBITER	S/C TOOLS	LIBRATION POINT S/C
CAPACITY (AH)	20-40	5-10	10, 20, 35	10, 20, 35	3-5 AH	20-25 AH
VOLTAGE (V)	28	28	28-100	28	28	28
DIS. RATE	C/5-1C	C/5-C/2	C/2	C/2-C	C/2	C/2
CYCLE LIFE	> 500 (>60%DOD)	>500 (>60% DOD)	2000 (>75% DOD)	>30,000 (>30% DOD)	>100	50
OPER. TEMP (C)	-40 TO 40	-40 TO 40	-5 TO 30	-5 TO 30	0-50C	25-30
SP. ENERGY (Wh/KG)*	>100	>100	>100	>100	>100	100
ENERGY DENSITY (Wh/l)*	120-160	120-160	120-160	120-160	>80	120-160

* 100% DOD BOL



AIRCRAFT BATTERY REQUIREMENTS

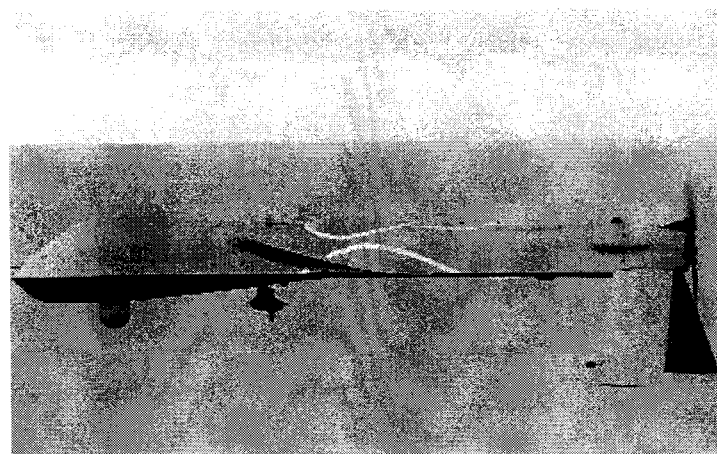


AIR CRAFT

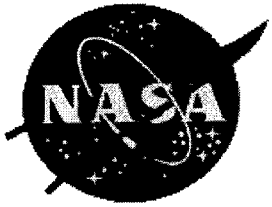


VOLTAGE: 28-270 V
CAPACITY: 5-20 Ah
DIS. RATE: 1C
CYCLE LIFE: 1000 (50% DOD)
OPER. TEMP: -40TO +65
SP. ENERGY: > 100 WH/KG

UAV'S



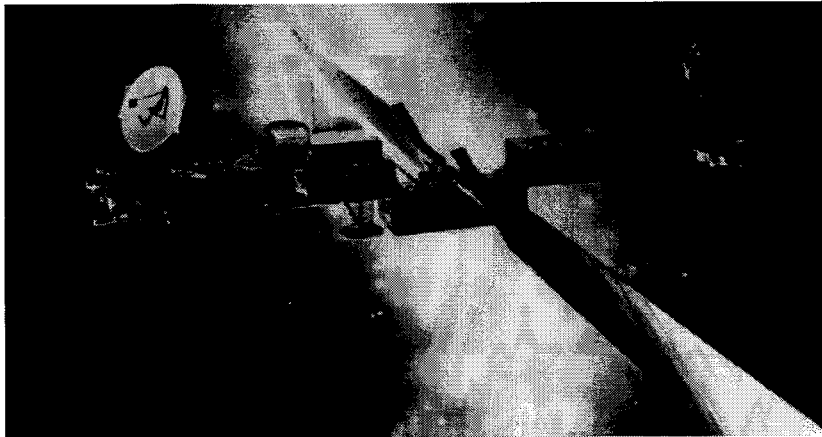
VOLTAGE: 28-100 V
CAPACITY: 100-200 Ah
DIS. RATE: C/5 TO 1C
CYCLE LIFE: 1000 (50% DOD)
OPER. TEMP: -40TO +65
SP. ENERGY: > 100 WH/KG



SPACECRAFT BATTERY REQUIREMENTS

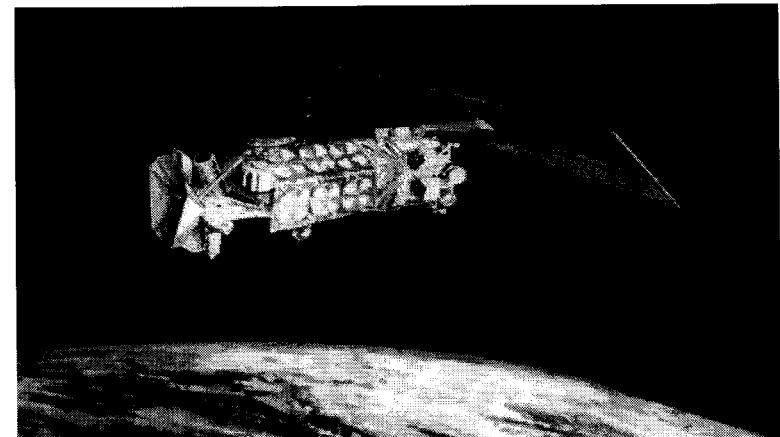


GEO SPACRAFT

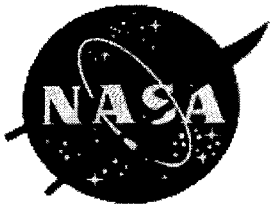


VOLTAGE: 28-100 V
CAPACITY: 40-50 Ah
DIS. RATE: C/2-2/3C
CYCLE LIFE: 1500 (50% DOD)
OP. LIFE: 10-15 YEARS
OPER. TEMP: 0 TO + 30
SP. ENERGY: > 100 WH/KG

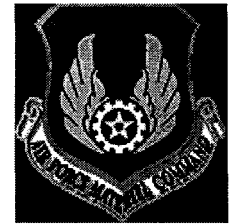
LEO SPACECRAFT



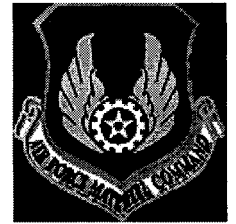
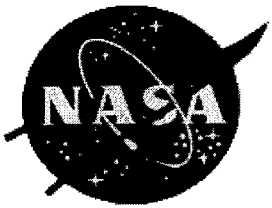
VOLTAGE: 28 V
CAPACITY: 50 Ah
DIS. RATE: > C/2
CYCLE LIFE: > 30,000 (25% DOD)
OP. LIFE: > 5 YEARS
OPER. TEMP: 0 TO + 30
SP. ENERGY: > 100 WH/KG



DOD Lithium-Ion Battery Performance Requirements

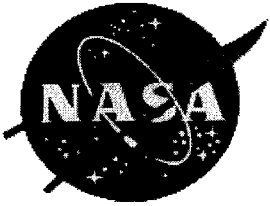


Type	Operating Voltage	Capacity (Ahr)	Temp. (°C)	Cycle Life	Discharge Rate Charge Rate	% DOD
UAVs	100	200	-40 to +65	1000	C C	50
Aircraft (a)	270	20	-40 to +65	1000	C C	50
Aircraft (b)	270	20	-40 to +65	1000	C C	50
GEO Sats	100	50	-5 to +30	1500	2/3 C C/20	75 (max)
LEO Sats	28	50	-5 to +30	45000	C C/2	25



JPL ROLE

- Provide Technology Guidance
- Transfer Inhouse Developed Technology (electrode materials, electrolytes, cell design, charge control methods)
- Support Project Manager in contract reviews
- Provide battery engineering support to 2001 Lander and 2003 Rover projects
- Co-ordinate in-house programs at Air Force Research Laboratories and NASA centers



TECHNOLOGY DRIVERS FOR FOR VARIOUS MISSIONS

MISSION	TECHNOLOGY DRIVER
LANDER/ROVER	LOW TEMP. OPERATION HIGH RATE PULSE CAPABILITY
GEO S/C	TEN-TWENTY YEAR OPERT. LIFE LARGE CAPACITY CELLS (50-200 Ah)
LEO/PLANETARY S/C	LONG CYCLE LIFE (30,000) MED. CAPACITY CELLS (50 Ah)
AIRCRAFT	LOW TEMP OPERATION HIGH VOLTAGE BATTERIES (270 V)
UAV	LARGE CAPACITY CELLS (200 Ah) HIGH VOLTAGE BATTERIES (100V)

OTHER CHALLENGES: RELIABILITY, SAFETY & COST



POTENTIAL NEAR TERM SPACE MISSIONS/APPLICATIONS



•NASA MISSIONS

•JPL

MARS LANDER AND ROVER -2001

MARS LANDER AND ROVER -2003

MARS SAMPLE RETURN MISSION - 2005

CHAMPOLILON MISSION - 2003

SOLAR PROBE - 2005

•GSFC

SATELITE SERVICING TOOLS
LIBRATION POINT SPACECRAFT
(MAP-2000,NGST 2007)

GEO SPACECRAFT(GOES)

LEO SPACECRAFT(EOS)

•AIR FORCE MISSIONS

•GEO

Milsatcom - 2002?

DSP - ?

•AIRCRAFT

AVIATION - 2001

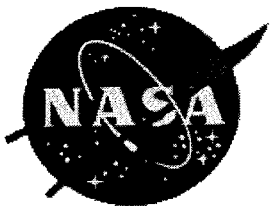
UAVs - 2001

LEO

SBIRS Low - 2004

NPOESS - 2007

Surveill. Platforms



MANAGEMENT APPROACH



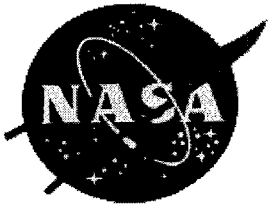
PARTICIPATING ORGANIZATIONS/AGENCIES INCLUDE:
NASA, AIRFORCE, BMDO, JIST.

DEVELOP TWO SOURCES FOR MANUFACTURING CELLS
AND BATTERIES

BUILD ON EXISTING COMMERCIAL TECHNOLOGY AND
GOVT TECHNOLOGY DEVELOPMENT EFFORTS/PROGRAMS

TEAMING OF UNIVERSITIES, R&D ORGANIZATIONS AND
BATTERY MANUFACTURING COMPANIES IS ENCOURAGED

NASA, AIRFORCE, NAVY LABS AND AEROSPACE PRIMES
PARTICIPATE IN TECHNOLOGY EVALUATION FOR VARIOUS
MISSIONS



-SPACE

TECHNOLOGY APPROACH



DEVELOP ADVANCED ELECTRODE MATERIALS AND ELECTROLYTES TO ACHIEVE IMPROVED LOW TEMPERATURE PERFORMANCE AND LONG CYCLE LIFE

OPTIMIZE CELL DESIGN TO IMPROVE SPECIFIC ENERGY, CYCLE LIFE AND SAFETY

ESTABLISH MANUFACTURING PROCESSES TO ENSURE PREDICTABLE PERFORMANCE

DEVELOP AEROSPACE LITHIUM ION CELLS IN 5, 10, 20, 50, AND 200 AH SIZES

DEVELOP BATTERIES IN 28, 100 AND 270 V CONFIGURATIONS

DEVELOP ELECTRONICS FOR SMART BATTERY MANAGEMENT

DEVELOP A PERFORMANCE DATABASE REQUIRED FOR VARIOUS APPLICATIONS

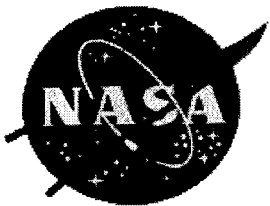
DEMONSTRATE TECHNOLOGY READINESS FOR VARIOUS NASA AND AIR FORCE MISSIONS



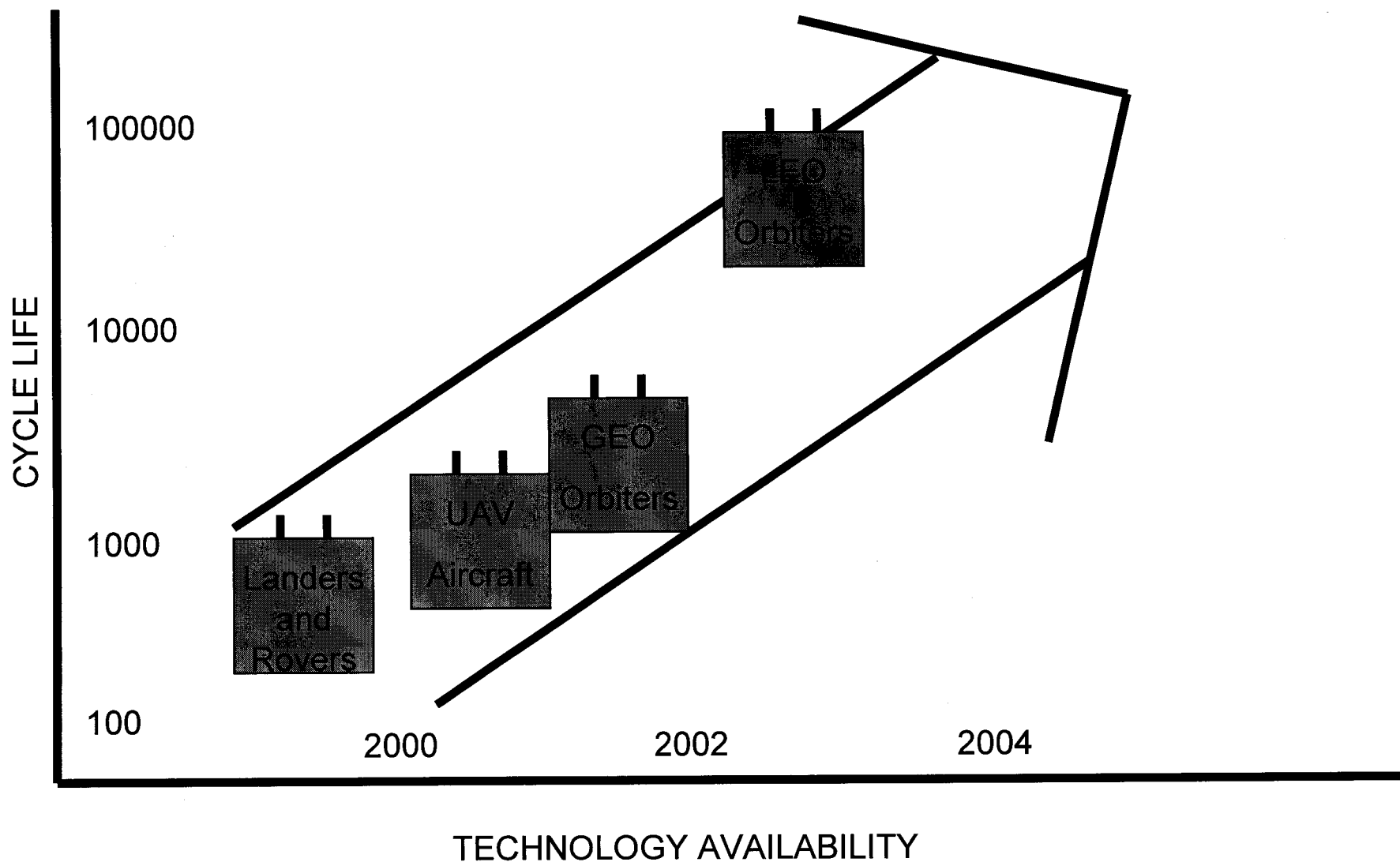
AEROSPACE LITHIUM-ION BATTERY PROGRAM ROADMAP

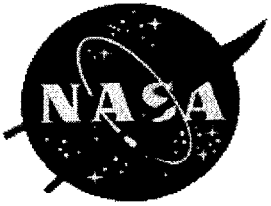


TASK	98	99	00	01	02	03	04	GOALS
CHEMISTRY & MATERIALS	<p>LOW TEMP. AND STABLE E'LYTE</p> <p>HIGH CAP. & LONG LIFE ELECTRODES</p> <p>SEPARATOR OC/OD ADDITIVES</p>							IMPROVE - LOW TEMP. PERF. - CYCLE LIFE - OPERATIONAL LIFE
CELL DEVELOPMENT	<p>PROCESS DEV. DESIGN, AND CELL MANUFACTURING</p> <p>10-20 Ah, 500 CYC LT, HR, 200 Ah</p> <p>40/50 Ah, 2000 CYC 30000 CYCLE, 20-50 Ah</p>							EST. MANF. PROCESS OPT. CELL DESIGN FAB. 10-200 Ah CELLS
BATTERY DEVELOPMENT	<p>PROCESS DEV. DESIGN & MANF.</p> <p>LANDER/ROV UAV/AIRCRAFT</p> <p>GEO S/C LEO, PLANETARY S/C</p>							EST. MANF. PROCESS DEV. SMART BATT. FAB. LANDER, ROVER GEO, LEO S/C, UAV AIRCRAFT BATT.
TESTING & QUALIFICATION	<p>ELECTRICAL PERE., THERMAL, AND SAFETY TESTS</p> <p>100/50% DOD LEO & GEO LIFE TEST</p> <p>FAILURE MODES & ANALYSIS</p>							EST. DATA BASE DET. FAILURE MODES EST. CHARGE CNTLS DEMON. SAFETY
FLIGHT VALIDATION	<p>LAND/ROVER S/C TOOLS UAV/AIRCRAFT GEO S/C LEO S/C</p>							DEMON. TECH. FOR LANDER, ROVER GEO, LEO S/C, UAV AIRCRAFT MISSIONS



TECHNOLOGY DEMONSTRATION MILESTONES





Acknowledgments

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